Installation and Integration of the Electronics at the MINOS Far Detector

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1 Front End Electronics

The Front end electronics consists of two types of components, the VA Front end Boards (VFB) which mount directly to the Mux boxes and the VA Readout Controllers (VARC) which reside in a VME crate. There are signal and control cables which run between the two and there are DC voltage power cables which run from power supplies distribution panels near the VARC crates to the VFBs. Details of the specifications and design of this system can be found in http://heplpc6.harvard.edu/minos_Docs/docs.

VA Front End Boards

The VFBs are 3" x 8" PC boards that mount via standoffs to the side of the mux boxes. There is a connector on them which mates to a connector on the Mux box light seal and makes the required electrical connections from inside the Mux box to the VFB circuitry. In order to eliminate potential noise pickup and grounding problems, the VFB will be covered with a small metal 'box' which is open on the side towards the Mux box. This box will be electrically connected to the Mux box housing and together they form a Faraday cage around the VFB. The grounding of this system will come only through the electrical connections to the VFB and through the HV for the M-16 PMTs. There should be no other grounds to the Mux box! Some drawings of this can be found at http://mimosa.astro.indiana.edu/minos/mux_box/index.html.

There are four types of cables coming into the VFB. On one of the 3" sides will be the electrical connections that will come through a cutout in the cover box. These include a flat ribbon cable which is about 1.25" wide (50 conductors with 25 mil pitch), a power cable which is ~1/4" diameter and is a shielded cable containing 2 twisted pairs, and a special low dispersion cable which is ~1/8" diameter. On the other 3" side there are two fiber optic cables that come from the LED flasher system and connect to the PIN diodes on the VFB board. These will plug in through holes in the cover box that align with fiber optic connectors on the board. The electrical cables should run together in a bundle (along with the HV cables going to the Mux box) to avoid potential ground loops.

VA Readout Controllers

These boards go into a 9U VME crate. Each one will handle 12 VFB boards. They will need 2 slots in the VME crates so that some of the cabling can reach back to their connectors. These connectors will be on the VARC Mezzanine Modules (VMM) that plugs into the VARC. Also in the VME crate will be the Clock Receiver board and the Readout Processor (ROP) with its PVIC interconnect module (described later). The clock receivers will have (probably optically) distributed clock signals coming to it. In addition there will be power supplies for the VME crate and +/- 5 V for the VFBs in this rack.

Locations

The VFBs will be mounted on the Mux boxes. These are located in racks on the top and bottom walkways on either side of the Super Modules. They will be accessible from the sides of the rack. The VARC crates will be located in racks on the midlevel walkways. Their vertical position in the racks will be adjusted to minimize the longest cable lengths from them to the VFBs. The cables will run in a bundle from the VARCs vertically in the rack to a cable tray that runs horizontally (Z-direction) under the walkways. These trays will carry them horizontally over to the rack containing the appropriate VFB/Mux Box. The cables will then again run vertically in the rack until the cables reach their connectors. It is important to minimize the length of the cables. The cable needed to bring the analog VA signals to their ADC drives this. Samples of this cable at 22' are currently being purchased for testing - shorter would be better!

Installation

The steady state front-end electronics installation will be one VFB and one cable bundle per day. The VARCs are needed only about one every 2 weeks. In practice, the VFB's will be installed with the Mux box. This could be either by attaching the VFB and its cover box to the Mux box and installing this as a unit, or by installing the Mux box first and attaching the VFB/cover once it is in place (the latter seems to be preferred by the Mux box people).

Cabling would be done by running all the cables needed for a given VFB rack at once, before the Mux boxes arrive. The connectors would have to be protected so that they weren't damaged by the Mux box installation. The cable bundles would be pre-made to length, and be strung along their routes. The cables would be pre-made and tested before coming to the mine, although this work could be done at the mine if necessary.

The VARC's, crates and power supplies would be installed into a rack before it was needed for plane readout. This would be done at the mine. The whole rack could be 'filled' away from the detector and moved into place or 'filled' in place. The former is preferable since the work can be done in a nicer environment. This depends on being able to move heavy racks into place on the midlevel walkway.

The actual physical installation will require less than 1 FTE technician, although there will be short periods where more than one person is needed (e.g. feeding cables through trays…)

Once a new VFB is connected, the electronics chain would be tested running a series of charge injection events to make sure the signals are getting through properly, that all channels are being read out and that they all respond correctly over their dynamic ranges. Then tests would be run in conjunction with the new PMTs: tests to make sure the dynode signals are getting through, that the thresholds are reasonable, that the tubes aren't too noisy, and if it is implemented, that the radioactive source produced a reasonable counting rate. The electronics-only portion would be special mode of the DAQ system and would last about 2-3 hours. The tests could eventually be done by a good electronics technician, but initially they would be done by physicist/students along with the technician.

All electronics will have been tested before coming to the mine. There will be sufficient spares of all components there at all times to be able to swap out suspect parts with good parts. Simple tests and fixes can be done at the mine (e.g. blown fuses), but most repairs would be sent offsite.

After being swapped out and checked in a test setup to be sure they are bad, malfunctioning VARC's, VMM's and VFB's will be returned to Fermilab for repairs, but difficult repairs will have to go back to Harvard or Oxford.

During the initial installation there will be much more work than there will be later, as the system has to be brought online, the local staff trained and the system 'debugged'. During this 3 month period, the engineers who designed/tested it would be there and would work along with 1-2 physicists who had been involved in the testing.

2 DAQ System

Description

The DAQ system carries the data from the Front end VARCs to the Trigger Processors and then passes it to the data archive and the offline analysis. At the front ends this starts with the Readout Processors (ROPs) of which there is one per VARC VME crate. There are 16 ROPs, one each in the 16 VME crates. They are logically grouped into four groups of four. Internally, each group (probably one side of a Super Module) will be connected together by PVIC running on electrical cables. These will connect to the ROPs on mezzanine cards. One of the ROPs for each of the four groups will also have an optical PVIC network card that is a separate VME card. From here there will be optical fibers running to a central location where the Readout Controller and the Trigger Processors sit. This can be a fairly long run. Each processor (ROP, ROC, Trigger Processor) will need to have an Ethernet LAN connection. Details of the specification and design of the system can be found at http://hepunx.rl.ac.uk/minos/daq/

Locations

The ROPs have to be in the same VME crates as the VARCs and will thus be in crates on the midlevel walkways. There will be 4 per side per super module spaced approximately evenly along the length of the detector. The electrical PVIC cables are ~1/2" diameter and will run from the ROP vertically to the horizontal trays and then over to the next ROP crate where they drop out again. Finally, the four optical PVICs run along the detector to the end and over to the Trigger Farm location. This can be reasonably far away (in the cavern, not on the surface though!). It would be preferable to have it in a clean and noise free location. For operational ease, it would be nice to have it near the Run control computer and near offline computers. There have to be Ethernet LAN connections for the various computers. Space in the Soudan Hall counting house would be ideal, but a work area on the MINOS Hall mezzanine would suffice (is there welding and grinding going on right under this?). If there is a Control Room or Area these should be there.

Installation

Physical installation will not require much effort. A new ROP is needed every few months. The PVIC cabling would be installed before it is needed although the connectors would have to be protected. It makes sense to have the LAN installed all along the detector before installation starts since many computers/devices will need to plug into it. .

Once a new VARC crate with its ROP is installed, the LAN and PVIC connections will be checked by passing test data along it to and from the ROP. A working VARC would then be plugged in and tests would be done to see that it can properly be addressed, and readout. These tests would be special modes of the DAQ and would take a few hours. The tests could eventually be done by a good electronics/computer technician, but initially they would be done by physicist/students along with the technician.

All electronics will have been tested before coming to the mine. There will be sufficient spares of all components there at all times to be able to swap out suspect parts with good parts. Simple tests and fixes can be done at the mine, but most repairs would be sent offsite.

During the initial installation there will be much more work than later as the system has to be brought online, the local staff trained and the system 'debugged'. During this 3-month period, the hardware and software engineers who designed/tested it would be there and would work along with 1-2 physicists who had been involved in the testing.

The longer-term upkeep will be done by experts on shift, usually physicists or students, with the original designers available as a backup.

Malfunctioning units will be swapped out and checked in a test setup to be sure they are bad. Crates and power supplies will be returned to Fermilab for repair. VME processors and PVIC interface cards will be returned to RAL for repair or return to the manufacturer.

3 Detector Control System

Description

The DCS consists of a central PC computer which runs the supervisory control program and a number of remote buses or devices from which it gets measurements and to which it sends control commands. The connection between the PC and the remote devices is through the main experiment Ethernet LAN. The remote busses can be of many different sorts and will each have at least one Ethernet adapter interface. For example the High Voltage system is controlled through the RS-232 bus of which there will be several to reach all the LeCroy 1440 HV units. Details of the specification and design of the system can be found at http://klong2.physics.wisc.edu/~theoalex/dcs_web/

Locations

The Control PC can be located anywhere on the LAN. If there is a 'control room' area, that would be a nice location for it. This could be in the Soudan Hall counting room or in a work area on the MINOS Hall mezzanine. The Ethernet adapters for the various busses and devices are very small; an RS-232 to Ethernet adapter is 'pocket sized' and a National Instruments Field Point controller is 3"x5"x3". These could be mounted on cable trays, on rack structure or several put on a rack panel. Their location is not critical but should be close to the Ethernet. The DCS system includes some of the devices that it controls (some are 'owned' by other subsystems) and these will have to be placed where they are needed for their function.

Components

Rack Monitors
There will be a rack monitor in every relay rack which has custom electronics and which uses AC power to monitor temperature, power supplies, air flow… These will be BiRa devices similar to those used by D0 although these have more functions than we need. A simple smoke detector will be in the front-end racks where no AC power is used. These will be monitored by the full rack monitors in the powered racks.

HV control/monitor
The LeCroy 1440 is readout and controlled by an RS-232 bus. It is expected that there will be 4 separate busses to control all the 1440's.

Electronics system
The electronics system is expected to provide all it's information to the DCS through a single interface point. This will be a connection on the ROC.

Environmental
Sensors to measure temperature, humidity, and airflow… will be located at various places around the cavern. They will connect to a few NI Field Point Controllers which can handle >100 inputs.

Magnet
The magnets will have an integrating coil for each plane, readout out by their own PCs and passed to the DCS via Ethernet. There may also be several Hall probe gaussmeters through out the detector.

Installation

It is expect that the system will be ready at the time when the first planes are installed. That means that a subset of the sensors/busses are in place, tested and working, and that the system is ready to be expanded as more of the detector comes on. So the first of the HV controls, environmental monitors… will be there, but the rack monitors, hall probes… will be added as needed.

The initial setup and checkout will be done by the people who designed the system. They will also train technicians on how to install new pieces and physicists/students on installation as well as operation of the system. This period will last about 3 months. The physical installation will involve stringing bus cables, mounting Ethernet interfaces and attaching transducers. It will also mean mounting patch panels where signals are interfaced to the control system. In the steady state this is expected to take less than 1 FTE technician. Checkout of the new components will involve telling the software about them and testing it to make sure that the device being controlled/monitored can be put through its paces. For different systems this will involve different procedures. The checkout will be performed by the physicists/students on shift.

Malfunctioning units will be swapped out and checked in a test setup to be sure it is bad. Rack protection and Ethernet interface units will then be returned to Fermilab for repair.

4 High Voltage

Description

The High Voltage system is based on the LeCroy 1440 system. It will consist of mainframes containing HV modules. Each module has 16 HV outputs, which will be limited to 1000V. The HV will be distributed on coax cables (probably RG-58 with SHV connectors) from the 1440 system to connectors on the mux boxes. There will be one channel/cable for each of the M16 PMTs.

The 1440 system is known to be sensitive to AC power fluctuations and to protect against this they will have ferroresonant transformers to filter and stabilize the power going in to them.

Location

The LeCroy 1440 mainframes will be located in racks on the midlevel walkways with 2 per side per supermodule. The ferroresonant transformers will be located next to the racks. The cables will leave the HV modules run vertically to one of the Z cable trays, then horizontally to the appropriate front end crate. Where possible, the cables should run close to the cables going from the readout VME crates to the same front end crate to minimize ground loops.

Installation

A new mainframe will be installed about every 3 months. These should be installed and tested before the mux boxes it supplies are installed. The LeCroy system will be pre-certified by PREP at Fermilab before it is shipped to the mine. When it is installed it will be tested by running each channel up to voltage and monitoring the current drawn. This will be done first with no cable and then once the cable is connected (but before being attached to the mux boxes).

The cables can be run at the time the mainframe goes in or later as needed for the mux boxes. If they are not in use the connectors should be protected until they are needed. The cables will be pre-assembled and tested, although this could be done at the mine if necessary. The cables will be checked for continuity when they arrive at the mine. They can also be tested at voltage if it proves necessary prior to installation.

Installing and checking out a mainframe will take ~2 days for 1-2 people. Installing the cables for it will take ~1 days for 2 people including the checkout. Initially the experts will do this work to prefect the method and to train the local crew. In the steady state it is expected that the installation will be done by the mine crew and the checkout by the physicists on shift with help from the crew.

A malfunctioning unit will be swapped out and checked in a test setup to be sure it is bad. If it is it will be returned to Fermilab PREP for repairs.

5 Clock

Description

The clock system is based on a GPS time standard. The output of the GPS antenna will be converted to optical signals and sent on an optical fiber to the receiver. There it will be converted back to electrical to extract the time signals. The receiver will put out a 10MHz signal and a 1 Hz tick. It will have the ability to provide a timestamp for an input signal sent to it and finally it will be the source of the Network Time Protocol (NTP) used to synchronize the various PCs on the mine LAN (good to at best 1ms). The clock signals are distributed from the GPS to the readout crates on optical fibers. There will be VME distribution boards which drive the fibers and, in the readout crates, VME clock receiver cards.

Location

The antenna will be located on the surface (obviously) mounted on the roof of the Dry House park building. It will be housed in a small heated enclosure. The optical converter will be in the Dry House and will need AC power. The antenna fiber will then go down the shaft and into the MINOS cavern. An additional spare fiber in the shaft should be included for this purpose. The GPS receiver and the clock distribution drivers will be mounted in a relay rack. This can be up to 200m from the furthest point of the detector – which could be in the Control room or along the detector. About 9U worth of rack space will be needed, equally divided between the GPS receiver, the timing central unit and the timing system PC. LAN connections to the PC and the receiver are needed, both to communicate with them and to provide the NTP service to all the LANs.

The fiber to the readout crates will run from the central timing unit in the cable trays.

Installation

It is expected that the whole GPS system (antenna, optical antenna connection, receiver and NTP) will be commercial. The clock distribution driver and receiver cards and the distribution cables will be custom made. A receiver card will be installed in a new readout crate every few months. The fibers to it will be also be needed then.

6 Installation Overview and Order

It is expected that the first shipments of all components will be at the mine on 1-March. There will be a period of installation and commissioning before the systems are ready to readout the first plane. Since checkout and monitoring of some systems depends on other system there is an (approximate) order in which initial installation should occur.

1. LAN systems
   Needed to communicate with any of the computers or monitor/control the detector
   Connections to the outside world are useful, but not absolutely necessary
2. GPS fiber down the shaft
   Needed for the GPS receiver
3. DCS system
   Needed to control/monitor the detector
   Can go in any time after the LAN
4. HV racks and crates
   Can go in any time after the DCS

5. DAQ: ROC and Trigger computers
   Can go in any time after the LAN
6. GPS receiver, antenna and central clock system
   Can go in any time after the fiber is down the mine
7. First Readout Racks and VME crates
   Can go in anytime, but can't be monitored until the DCS is there
   Can't be checked out with out the DAQ
8. Clock distribution system
   Needs GPS receiver, central clock and readout racks
9. DAQ: PVIC network cables and the first ROP
   Needed to connect the DAQ with the ROPs for readout crate checkout
10. First Front-end racks
    Can go in any time
11. HV cabling
    Can go in any time, but best after HV crates and the front-end racks are there
12. Readout to front end cabling
    Needed along with the Readout Crates to power and checkout the VFBs
13. Mux box with VFB
    Need the Front-end racks to hold them
    Need HV cabling to power/test PMTs

7 Control Room

The control room is thought of as an area where the computers and electronics that aren't needed right on the detector are located. It will be where the people on shift can have easy access to all the information they need. It should be relatively quiet, enclosed and have room for all the computers and electronics as well desk space for 3-4 people. These might be the people on shift, and experts working on their systems.

The electronics group would like to have the following in the control room:

- DCS computer
- ROC computers: up to 4, don't need individual monitors
- Trigger Farm computers: up to 5, don't need individual monitors
- DAQ computer
- Database computer
- Tape storage unit for backups and raw data
- Disk arrays for the DAQ and Database computers
- Internet connections to the outside world: for data to the Feynman Computing Center
- LAN connections for all systems in the mine
- Printer
- Telephone connections

Items that might be there:

- GPS clock receiver
- Clock system PC
- Clock distribution system

8 Shipping, Storage and Space requirement

Most of the electronics components will be quite small and not require much storage. The largest items will be the readout crates and the computers. After an initial shipment (about ½ of a supermodule) items will arrive as needed.

A testing space will be needed. It should have several electronics work benches and room for a few PCs and racks it will need LAN connections. A complete Front end to DAQ 'slice' will be needed. This will require about 3 racks. Smaller systems for the DCS and the HV will be needed too. There will also be cable and fiber testing facilities.

Generally it is expected that an area the size of the Soudan 2 'clean mezzanine' will be sufficient for the storage and the testing requirements.

9 Effort Estimates

All effort estimates are divided into an initial installation/commissioning/training period and a steady state period. The initial period is assumed to be 3 months long. During this time the designers and experts will be present to get their system working. During the steady state period most of the work will be done by the shift physicists and the mine crew technicians. There will only be occasional visits by the experts and their technicians when problems arise.

Front-ends

Initial period – John Oliver, Nathan Felt and Phil Sullivan will be there for the first 3 months about half time. They will need help from 0.5 FTE mine crew technicians and may bring technicians of their own. Physicist effort of about 0.5 FTE will also be needed.

Install VFBs and cables - this is expected to happen in units of one rack, so every 4 days. The VFBs are attached to the mux box and put in the racks. The four cables assemblies will be pre-assembled and run in the cable trays. Testing will be with the DAQ system in a special mode. Total time: 1 Physicist + 1 mine crew for 1 day.

Install VARC – this happens about once every 2 weeks. This involves plugging in the VARC and testing it through the DAQ readout chain. Total time: Installation 10minutes, Checkout – 2 hours for a physcist.

DAQ

Initial period – Geoff Pearce, Saeed Madani and Tim Nichols or the new post-doc from RAL will be there for the first 3 months about half time. They will need help from 0.25 FTE mine crew technicians and may bring technicians of their own. Physicist effort of about 0.5 FTE will also be needed.

Installing a Readout Crate – This happens every few months. This involves putting in the crates, the power supplies, and power distribution panels. Then they must be wired up. Finally the ROP and PVIC are connected. Once connected the readout chain is tested with a special DAQ mode. Total time: Installation, Connection, checking - 1 physicist+1 mine crew technician for one day. Checkout of readout – .5 physicist for one day

Installing the ROCs, Trigger Farms processors, and the DAQ computer. This happens once and is done during the initial period.

DCS

Initial period – Marvin Marshak, 2 postdocs/students from Minnesota and Wisconsin will be there for the first 3 months about half time. Jeff MacDonald will be there ~0.25 of the time They will need help from 0.25 FTE mine crew technicians and may bring technicians of their own. Physicist effort of about 0.5 FTE will also be needed.

Installing the DCS computer – This is done once during the initial period.

Installing new devices – the most common are the rack protection systems and happens every few weeks. It involves putting the unit into the rack, connecting its sensors (which may include smoke detectors in remote racks) and connecting it to the Ethernet. A check out will then be done (this will include seeing that the various sensors are active) . Total time – installation 1 mine crew technician and .2 physicist for 1 day. Checkout - 1 physicist for .5 day

HV

Initial period – Bob Webb and the TAMU technician will be there for the first 3 months about 0.25 time. They will need help from 0.25 FTE mine crew. Physicist effort of about 0.25 FTE will also be needed.

Installing a 1440 mainframe – this happens every 3 months and involves installing the crate, connecting it to the ferroresonant transformer and to the DCS. Tests are done to check it power supplies, DCS communications and a few HV modules. Total time: Installation .5 mine crew technician + 1 physicist for 1 day

Stringing the HV cable for one front-end rack – This happens every 4 days and involves testing the cables, and stringing them. Total time: 1 mine crew technician + 1 physicist for 1 day

Clock

Initial period – Colin Perry and Alfons Weber will be there for the first 3 months about 0.3 time. They will need help from 0.25 FTE mine crew technicians and may bring technicians of their own. Physicist effort of about 0.5 FTE will also be needed.

Installing the GPS receiver – this is done once and is part of the initial period

Preparing the optical cables – this happens once every few months. It involves measuring, cutting and terminating the optical fiber cables. Test will be done for transmission quality and optical length. Total time – 1 mine crew technician for .5 days, 1 physicist for .5 days.

Installing the distribution system for one readout crate - this happens every few months. It involves stringing the optical fibers from the central clock to the readout crate, plugging in a clock receiver card and connecting them. A test is then done to determine that the system is working. Total time: installation 1 physicist + 1 mine crew technician for .5 days, Checkout 1 physicist for .5 days.

Effort Summary Table

Table 1 The table shows the effort levels needed during the initial installation/ commissioning/ training period and the longer term steady state installation. The transition between them will not be sharply defined. Engineers come from the institution which designed/built the system and may include the physicist who designed/oversaw the system, Technicians come from the mine crew and Phys/Student are the experimenters on shift at the mine. This assumes 200 working days/year.

Subsystem	**Initial Period – 3 months**	**Steady State (FTEs)**
Front end	Engineers – 1.5 Technician - 0.5 Phys/Student – 0.5	Engineers – 0.13 Technician – 0.25 Phys/Student – 0.26
DAQ	Engineers/Designers – 1.5 Technician – 0.25 Phys/Student – 0.5	Engineers – 0.13 Technician - 0.06 Phys/Student – 0.1

DCS	Engineers/Designers – 1.75 Technician - 0.25 Phys/Student – 0,5	Engineers – 0.13 Technician - 0.13 Phys/Student – 0.1
HV	Engineer – 0.5 Technician – 0.25 Phys/Student – 0.25	Engineer – 0 Technician – 0.27 Phys/Student – 0.41
Clock	Engineer – 0.6 Technician – 0.25 Phys/Student – 0.5	Engineer – 0.13 Technician - 0.03 Phys/Student – 0.05
TOTAL	**Engineer – 5.85** **Technician – 1.5** **Phys/Student – 2.25**	**Engineer – 0.52** **Technician - 0.74** **Phys/Student – 0.92**